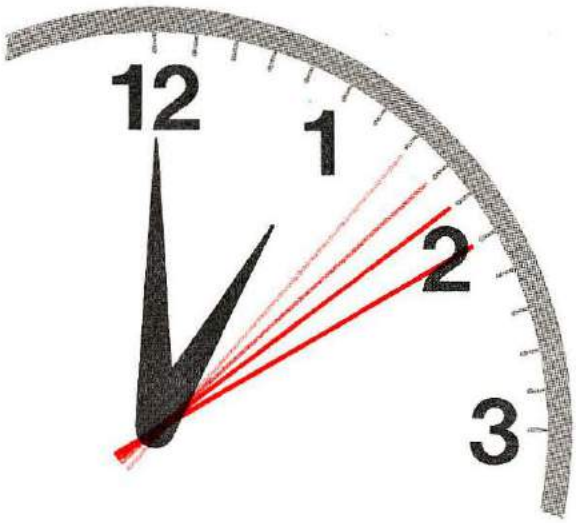


Time and Time Again

"When the tone returns, the exact time will be . . ."

BY JAMES H. GRAY, W2EUQ

"My watch has stopped again! What time is it, anyway?" Sound familiar? This scene is repeated daily, with variations, everywhere on earth by thousands of people in all walks of life. Like it or not, we live by the clock, and the world's work depends upon knowing what time it is.

Astronomers and observatories, airlines and marine shipping companies, electric power and telephone companies, radio and TV broadcasting stations, research laboratories, scientific and industrial organizations, navigators, and even Radio Amateurs and shortwave listeners have a need to know the correct time to successfully carry on their activities. Man regulates his life by the clock and apparently has always done so, even in prehistoric times, if the pyramids, Stonehenge, and Mayan sundials and calendars are meaningful.

Sundials gave way to water clocks which, in turn, yielded to weight-operated clocks, and finally to spring-driven timepieces. These familiar and ordinary watches and clocks, in turn, were replaced by electrically or electronically regulated devices which depend upon mechanical tuning forks or piezo electric crystal oscillators to provide increasingly accurate time information. For laboratory and similar standards, even these aren't accurate enough, and the major standards are now controlled by "atomic clocks," in which atoms of the elements cesium or rubidium provide the frequency — hence, time — control.

In the United States, the National Bureau of Standards operates radio stations WWV, WWVH, WWVB, and WWVL which provide standard signals together with many other useful services; and in Canada, the National Research Council operates radio station CHU, which provides the time service.

Let's take a look at these two major facilities in more detail, with an eye toward the type of

A view of both WWVB/WWVL and WWV (right) from the top of one of the antenna-support towers. The steering-wheel-like objects at the lower left are anti-static or anti-corona devices (*photo courtesy US Department of Commerce*).

information that is provided and by what means.

WWV and WWVH

For more than 50 years, the National Bureau of Standards, (NBS), under the United States Department of Commerce, has provided internationally-recognized time and frequency standards for worldwide users of this service.

Since the inception of the broadcast services from radio station WWV in 1923, NBS has continually improved and expanded its time and frequency dissemination services to meet the needs of a growing community of users in the United States and elsewhere. NBS has made, and continues to make, major contributions to the nation's space and defense programs, to worldwide transportation and communications, and to a multitude of industrial operations.

In addition, NBS provides a convenient, highly accurate time service to thousands of users throughout the world. Its services are available from station WWV and WWVB in Fort Collins, Colorado, and from WWVH in Kauai, Hawaii. Beyond this, a new calibration method using network television is also available.

NBS broadcasts continuous signals from its high-frequency radio stations WWV and WWVH on 2.5, 5, 10, and 15 MHz. These widely-spaced frequencies practically insure that users anywhere in the United States can receive at least one of them at any time of the day or night to receive needed time and frequency information. Except during times of severe magnetic disturbances, which tend to make all reception of radio transmission impossible, listeners will find that the frequencies above 10 MHz provide the best daytime reception, while frequencies below 10 MHz provide the best night-time reception.

Services provided by these stations include: time announcements, standard time intervals, standard frequencies, geophysical alerts, marine storm warnings, time corrections, and a BCD time code. The format of the broadcasts, and the hourly schedule is shown in **Fig. 1**.

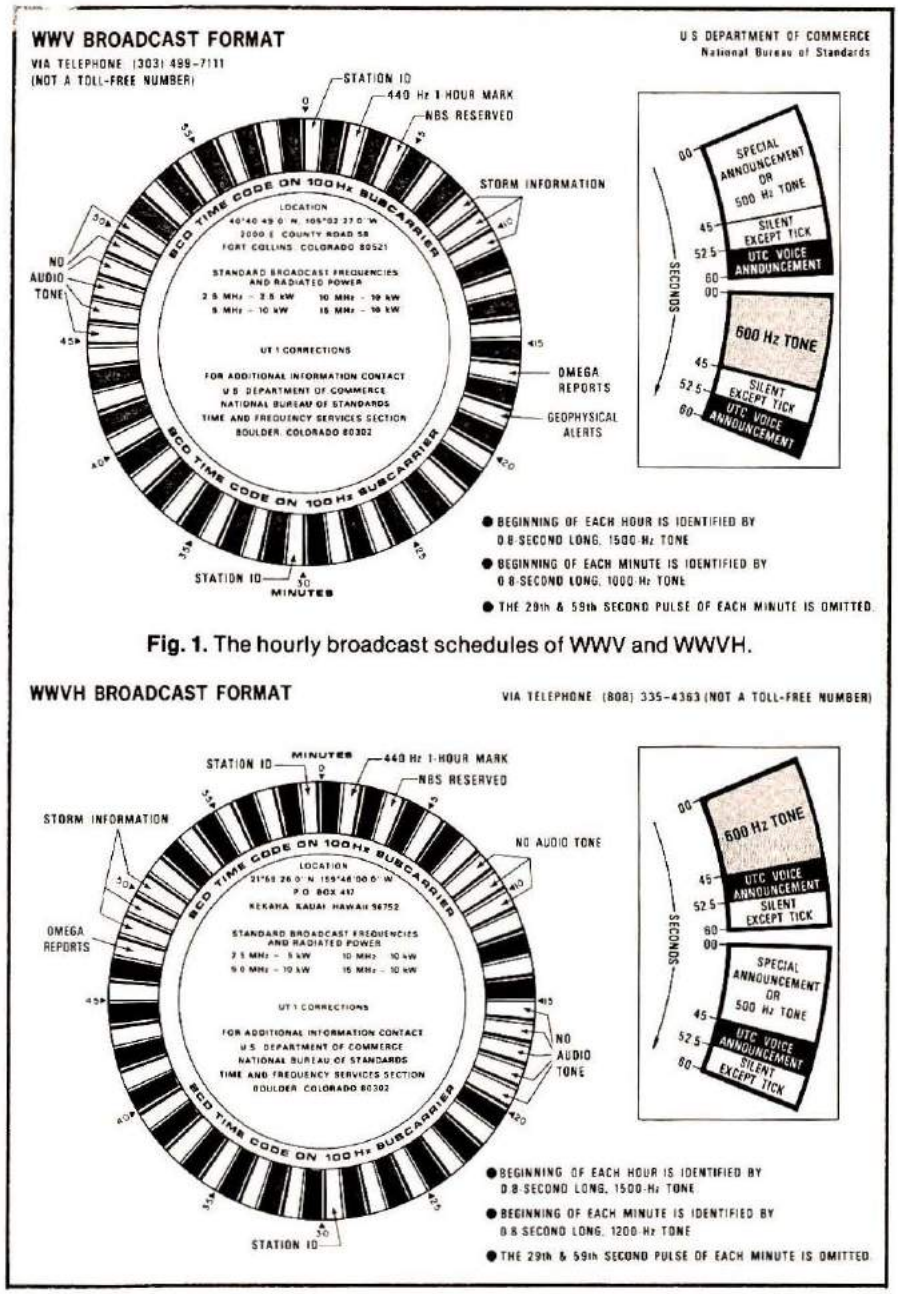

WWV BROADCAST FORMAT
VIA TELEPHONE (303) 499-7111
(NOT A TOLL-FREE NUMBER)
U S DEPARTMENT OF COMMERCE
National Bureau of Standards
STATION ID
440 Hz 1 HOUR MARK
NBS RESERVED
STORM INFORMATION
NO AUDIO TONE
OMEGA REPORTS
GEOPHYSICAL ALERTS
STATION ID
MINUTES
BCD TIME CODE ON 100 Hz SUBCARRIER
LOCATION
40°40 49.0" N 105°02 27.0" W
2000 E COUNTY ROAD 58
FORT COLLINS COLORADO 80521
STANDARD BROADCAST FREQUENCIES AND RADIATED POWER
2.5 MHz - 2.5 kW
5 MHz - 10 kW
10 MHz - 10 kW
15 MHz - 10 kW
UT1 CORRECTIONS
FOR ADDITIONAL INFORMATION CONTACT
U S DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
TIME AND FREQUENCY SERVICES SECTION
BOULDER COLORADO 80302
SECONDS
SPECIAL ANNOUNCEMENT OR 500 Hz TONE
SILENT EXCEPT TICK
UTC VOICE ANNOUNCEMENT
600 Hz TONE
SILENT EXCEPT TICK
UTC VOICE ANNOUNCEMENT
● BEGINNING OF EACH HOUR IS IDENTIFIED BY 0.8-SECOND LONG, 1500-Hz TONE
● BEGINNING OF EACH MINUTE IS IDENTIFIED BY 0.8-SECOND LONG, 1000-Hz TONE
● THE 29th & 59th SECOND PULSE OF EACH MINUTE IS OMITTED
WWVH BROADCAST FORMAT
VIA TELEPHONE (808) 335-4363 (NOT A TOLL-FREE NUMBER)
STATION ID
MINUTES
440 Hz 1-HOUR MARK
NBS RESERVED
STORM INFORMATION
NO AUDIO TONE
OMEGA REPORTS
NO AUDIO TONE
STATION ID
BCD TIME CODE ON 100 Hz SUBCARRIER
LOCATION
21°58 26.0" N 159°46 00.6" W
P.O. BOX 417
KEKAHA KAUAI HAWAII 96752
STANDARD BROADCAST FREQUENCIES AND RADIATED POWER
2.5 MHz - 5 kW
5.0 MHz - 10 kW
10 MHz - 10 kW
15 MHz - 10 kW
UT1 CORRECTIONS
FOR ADDITIONAL INFORMATION CONTACT
U S DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
TIME AND FREQUENCY SERVICES SECTION
BOULDER COLORADO 80302
SECONDS
600 Hz TONE
UTC VOICE ANNOUNCEMENT
SILENT EXCEPT TICK
SPECIAL ANNOUNCEMENT OR 500 Hz TONE
UTC VOICE ANNOUNCEMENT
SILENT EXCEPT TICK
● BEGINNING OF EACH HOUR IS IDENTIFIED BY 0.8-SECOND LONG, 1500-Hz TONE
● BEGINNING OF EACH MINUTE IS IDENTIFIED BY 0.8-SECOND LONG, 1200-Hz TONE
● THE 29th & 59th SECOND PULSE OF EACH MINUTE IS OMITTED

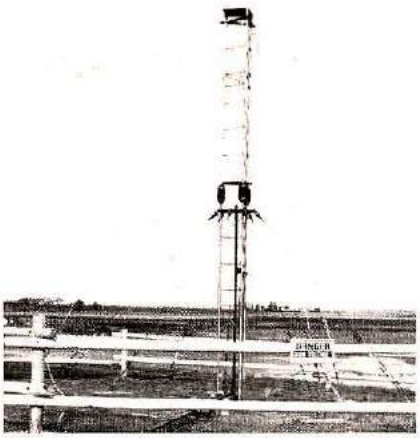
Fig. 1. The hourly broadcast schedules of WWV and WWVH.

Accuracy and stability

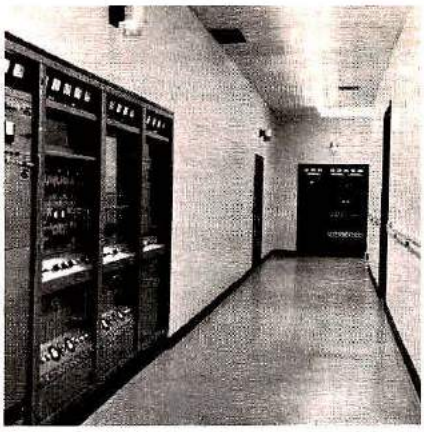
The NBS Primary Frequency Standard in Boulder, Colorado, controls all time and frequency broadcasts from its stations. The transmitted frequencies are accurate to *one part in 100 billion* at all times, and day-to-day deviations are normally less than *one part in 1000 billion*! Changes in the propagation medium, however, cause disturbances which result in fluctuations of the carrier frequency *as received* by the user. Such fluctuations can be much greater in magnitude than the uncertainty described above.

Time announcements

Voice announcements are made from WWV and WWVH once every minute and, to avoid confusion, a man's voice is used on WWV and a woman's



The 25-MHz dipole antenna near the WWV building. It is center fed by means of the 3-1/8 inch (8cm) transmission line you can see in the left foreground (*photo courtesy US Department of Commerce*).



The transmitters are located along corridors, with space behind the equipment racks for maintenance operations. These are in the WWV building (*photo courtesy US Department of Commerce*).

voice on WWVH. The WWVH announcement comes first, at 15 seconds before the minute — while the WWV announcement occurs at 7½ seconds before the minute. The tone markers, however, are broadcast simultaneously from both stations but may not be *received* simultaneously because of propagation effects.

The time referred to in the announcements is *Coordinated Universal Time* (UTC), meaning that it is coordinated by the International Time Bureau (BIH) through international agreements, so that time signals broadcast by the many nations which provide a time and frequency service will be in close agreement.

The specific hour and minute mentioned in the broadcasts is actually the time in the time zone centered around Greenwich, England, and may be considered generally equivalent to the better-known *Greenwich Mean Time* (GMT). UTC differs from your local time by an integral number of hours, depending upon the time zone in which you live.

Many charts and maps are available to help you find the time anywhere in the world at a given GMT, and some clocks have appropriate dials to automatically give both GMT and the time at various locations around the world. For example, Eastern *Standard* Time is five hours *behind* GMT, while Eastern Daylight Time is only four hours behind GMT.

The UTC time announcements are expressed in the 24-hour clock system — *i.e.*, the hours are numbered beginning with 00 hours at midnight through 12 hours at noon to 23 hours, 59 minutes just before the next midnight. Among the many Amateur Radio operators, you will find that DXers and OSCAR users almost invariably use GMT (UTC), or "Zulu" time, in preference to local time. This is done so that stations at both ends of the circuit can be talking about the same time on particular days, and not different times on different days.

"Zulu" time may sound strange, but the logic becomes obvious when you understand the background. For convenience in specifying time, the military has divided the earth into 24 time zones, and has assigned to each time zone a letter of the alphabet (see **Fig. 2**). The "Z" time zone happens to coincide with Greenwich, England through which the zero meridian of longitude passes. Inasmuch as the letter *Z* can be confused with the letter *C* in voice transmissions, it has become customary to assign phonetics to each letter of the alphabet. Quite naturally, Z became the phonetic "Zulu" or "Zebra". Hence Zulu time means GMT.

Standard time intervals

The sounds most frequently heard on WWV and WWVH are the pulses that mark the seconds of each minute, except for the 29th or 59th second pulses which are omitted completely. The first pulse of every *hour* is an 800-millisecond pulse of 1500 Hz. The first pulse of every *minute* is an 800-millisecond pulse of

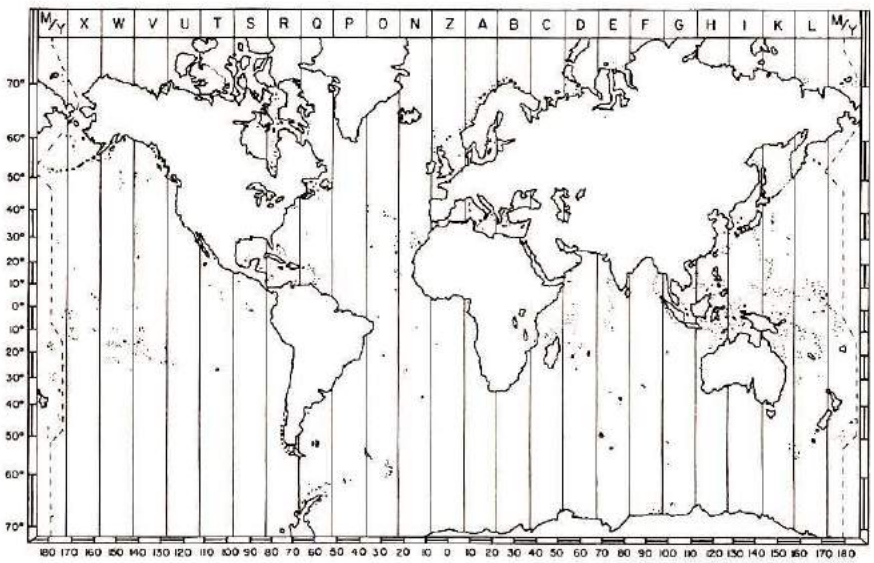


Fig. 2. World map showing the military time zones of the world identified by letter designators. Z (Zulu) time corresponds to GMT.

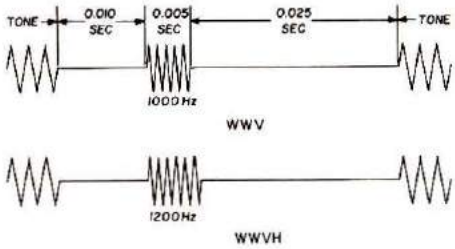


Fig. 3. Format of WWV and WWVH seconds pulses.

1000 Hz at WWV and 1200 Hz at WWVH. The remaining seconds pulse are brief audio bursts (5-millisecond pulses of 100 Hz at WWV and 1200 Hz at WWVH) that resemble the ticking of a clock. All pulses commence at the *beginning* of each second and are transmitted by means of double-sideband, amplitude modulation. Each seconds' pulse is preceded by 10 milliseconds of silence and followed by 25 milliseconds of silence to avoid interference which might make it difficult or impossible to pick out the seconds pulses. **Fig. 3** illustrates this total 40-millisecond protected zone surrounding each seconds pulse.

Standard audio frequencies

In alternate minutes during most of each hour, 500- or 600-Hz audio tones are broadcast. A 440-Hz tone, the musical note A above middle C, is broadcast once each hour. The 440-Hz tone, in addition to being a musical pitch standard, can also be used to provide an hourly marker for chart recorders, or other automatic devices.

Announcement segments of forty-five seconds' duration are available on a subscription basis to other Federal agencies to disseminate official and public service information. The accuracy and content of these announcements are the responsibility of the originating agency, not necessarily NBS.

Propagation forecasts. These useful forecasts, which occurred at 14 minutes past each hour, have been discontinued, some of the information contained in them has been transferred to the Geophysical Alerts segment of the format.

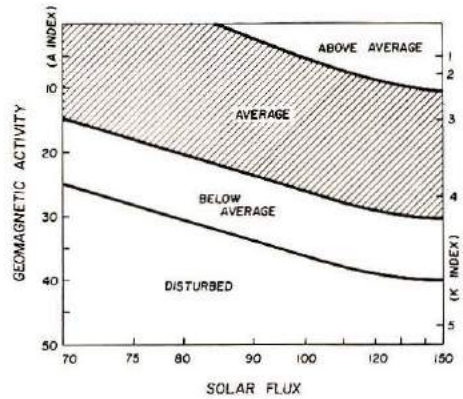


Fig. 4. Graph showing the relationship between Geomagnetic and Solar flux indexes, and their combined effect on ionospheric propagation of radio waves.

Geophysical alerts. Current alerts are broadcast in voice from WWV at 18 minutes after each hour, and from WWVH at 45 minutes after each hour. The messages are changed daily at 0400 UTC with provisions to

Table 1. High-frequency time and frequency-standard stations, listed by callsign.

Callsign	Location	Carrier Frequency (MHz)	Modulation*
ATA	New Delhi, India	10 & 15	1000 Hz + voice
CHU	Ottawa, Canada	3.330, 7.335 & 14.670	Voice
FFH	Paris, France	2.5	—
IBF	Rome, Italy	5	—
JJY	Tokyo, Japan	2.5, 5, 10, & 15	1000 Hz + voice
LOL	B. A., Argentina	5, 10 & 15	440 & 1000 Hz + voice
MSF	Rugby, England	2.5, 5, & 10	Voice
OMA	Prague, Czech.	2.5	1000 Hz
RAT	Moscow, USSR	2.5 & 5	10-second pulses
RCH	Tashkent, USSR	2.5	10-second pulses
RIM	Tashkent, USSR	5 & 10	10-second pulses
RWN	Moscow, USSR	10 & 15	10-second pulses
VNG	Lyndhurst Australia	4.5, 7.5, & 12	1000 Hz
WWV	Fort Collins Colorado, USA	2.5, 5, 10, & 15	440, 500, 600 & 1000 Hz + voice
WWVH	Kehaha, Hawaii	2.5, 5, 10, & 15	440, 500, 600, & 1200 Hz + voice
ZUO	Olifantsfontein, South Africa	2.5 & 5	—
GBR	Rugby, England	15.95 & 16 kHz	—
HBR	Pragins, Switzerland	75 kHz	—
JJF-2	Chiba, Japan	40 kHz	—
WWVB	Fort Collins Colorado, USA	60 kHz	—

*All stations broadcast basic one-second time pulses, but some have additional modulation, as indicated.

provide real-time data alerts of outstanding geophysical events. These are followed by a summary of selected solar and geophysical events during the previous 24 hours.

Among the various events of interest to Radio Amateurs for purposes of following radio propagation conditions, are the Solar Flux and the Geomagnetic *A* Indexes. For best propagation of radio signals on the high-frequency bands, a relatively high Solar Flux and low geomagnetic *A* Index are desirable. The Solar Flux is measured at 2800 MHz and consists of radio "noise" whose magnitude has proven to be analogous to the magnitude of the energies that excite the *E* and *F* layers of the ionosphere. Solar-flux magnitude ranges from about 68 to 150, and can be roughly equated to smoothed sunspot numbers and MUFs.

The Geomagnetic Activity *A* Index indicates how well the ionosphere has performed with respect to the reflection and/or absorption of radio signals, particularly in the polar regions. An *A* Index of 0-7 means excellent reflection of signals, whereas an Index of 50 or over would indicate that a major magnetic storm is taking place with severely disturbed, if not disrupted, radio propagation conditions. In-between values indicate the relative condition of the earth's electromagnetic field.

This building is where the low-frequency transmitters, for stations WWVB and WWVL, are located. The towers support large wire antennas, but the largest is out of the photograph to the left. Prospective visitors should check with the US Department of Commerce in Boulder, Colorado, about the availability of tours at the WWV transmitting site (*photo courtesy US Department of Commerce*).

The Solar *K* Index is also given on the 18-minute after the hour broadcasts, and is updated every six hours. The *K* Index ranges from 0 to 9 and corresponds to the *A* Index from 0 to 50, respectively.

Fig. 4 shows the relationship between the various indexes and expected radio propagation conditions.

Marine storm warnings. At 8, 9, and 10 minutes after each hour, weather information about major storms in the Atlantic and eastern North Pacific oceans is broadcast in voice by WWV. Similar storm warnings covering the eastern and central North Pacific are given from WWVH at 48, 49, and 50 minutes after each hour. Additional one-minute segments at 11 minutes after the hour (WWV) and 51 minutes after the hour can be utilized under unusually severe

The building for WWVH in Hawaii is no less neat and functional than its stateside counterparts (*photo courtesy US Department of Commerce*).

widespread storm conditions. The brief messages are designed to tell mariners about storms in their areas. If no storms exist, that information will also be given. The ocean areas for which the U. S. has warning responsibility have been delegated by international agreement.

The National Weather Service issues regular broadcasts at 0500, 1100, 1700, and 2300 UTC from WWV; and 0000, 0600, 1200, and 1800 UTC from WWVH. These broadcasts are updated effective with the next-scheduled announcement following the time of issue.

Silent periods. These are periods with no *tone* modulation, but with continuing carrier frequency, seconds' pulses, time announcements, and 100-Hz BCD time code. The main silent periods extend from 45 to 51 minutes after the hour on WWV and from 15 to 20 minutes after the hour on WWVH. An additional 3-minute period from 8 to 11 minutes after the hour is silent on WWVH.

BCD time code

A binary-coded decimal (BCD) time code is transmitted continuously by WWV and WWVH on a 100-Hz subcarrier, and provides a standard timing base for scientific observations made simultaneously from different locations, such as astronomical events for example, or signals telemetered from satellites, where time markers superimposed directly on the recording aids data analysis.

UT1 time corrections

The UTC time scale broadcast by WWV and WWVH runs at a rate that is almost perfectly constant because it is based on ultra-stable atomic clocks, and meets the needs of most users. Somewhat surprisingly, some users of this service need time signals that are not this stable. For navigation and satellite

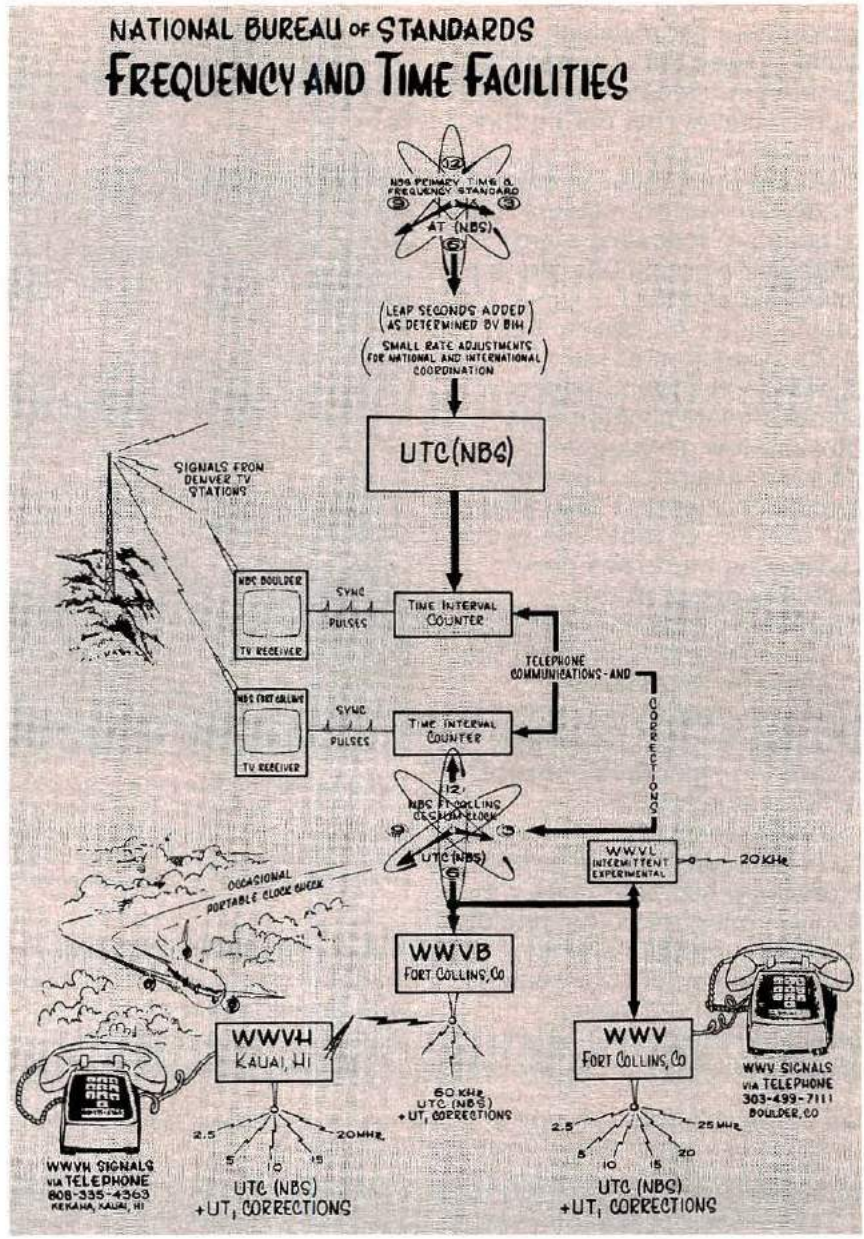


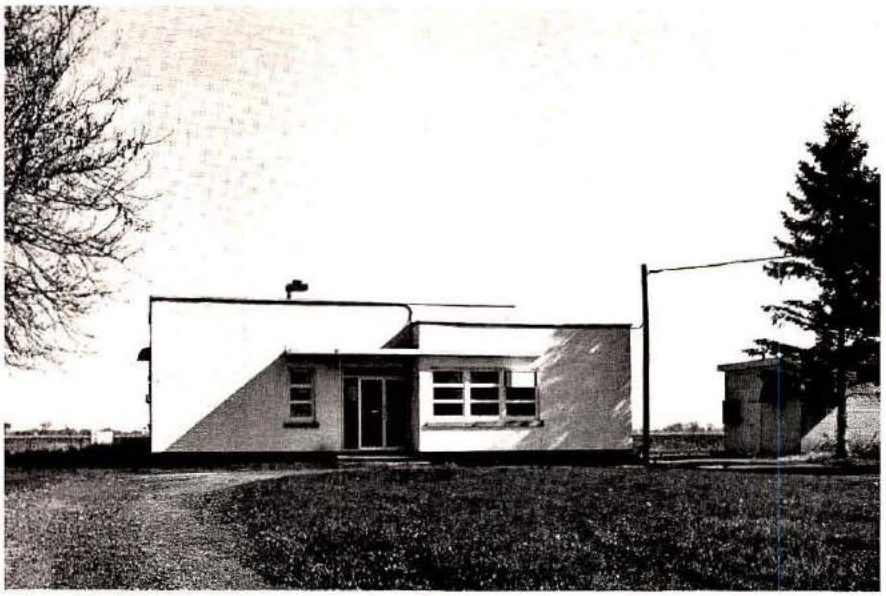
Fig. 5. The NBS frequency-control system.

tracking purposes, a time scale that slows down or speeds up with the earth's rotation must be used. The particular time scale needed is known as UT1 (inferred from astronomical observations) and is included in the UTC broadcasts at two levels of accuracy.

For those who need to know UT1 to only within about one second (most navigators), occasional corrections of exactly one second are inserted into the UTC time scale to keep UT1 and UTC time within plus or minus 0.9 second of each other. The correcting second insert is called a *leap second* and performs a function similar to that provided by the missing day every four years called *leap year*. As mentioned previously, the BIH regulates and coordinates the use of the leap second by international time and frequency broadcasting stations and bureaus of standards.

WWVB

WWVB transmits continuously on a standard radio carrier frequency of 60 kHz. Standard time signals,



The main building, left, and generator building, right, for time and frequency station CHU, in Canada (*photo courtesy Canadian National Research Council*).

time intervals, and UT1 corrections are provided by means of a BCD time code. The transmitting station is located on the same site as WWV, and effectively covers the entire continental United States. The frequency of WWVB is normally within its prescribed value to better than one part in 100 billion, and day-to-day deviations are normally less than 5 parts in 1000 billion. At this low carrier frequency, effects of the propagation medium on received signals are relatively minor; therefore frequency comparisons better than 1 part in 100 billion are possible by using appropriate receiving and averaging techniques.

WWVL

WWVL is an experimental station that broadcasts only on an intermittent basis, depending upon need and availability of funds. Transmissions can be made available on a subscription basis to public organizations and other Federal agencies.

Control of frequency

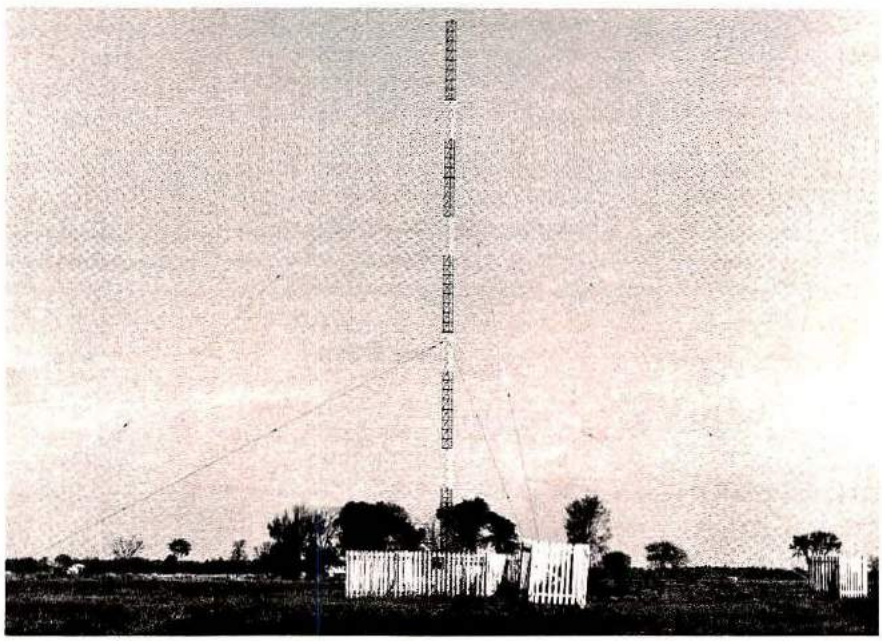
Fig. 5 is a simplified diagram of the NBS frequency control system, which depends upon the Primary Time and Frequency Standard. This standard includes a number of cesium-beam clocks, up to two primary cesium-beam frequency and time standards, and computer-aided measurement and computation methods which combine all of the clock data to generate an accurate and uniform time scale, called AT (UTC). Another scale, UTC (NBS), is also generated by adding leap seconds and small corrections to AT (UTC), as needed, to keep UTC (NBS) synchronized with the internationally-coordinated time scale, UTC, maintained by the BIH.

Canada — CHU

Astronomical observatories are always among the first facilities to generate and use accurate time information, furnished by daily — and nightly — observations of the sun, planets, and moons of our own solar system, as well as the stars of other systems. So it was in Canada, where radio time signals were first broadcast by radio during 1927 from the Dominion Observatory in Ottawa; although time signals had been sent over telephone lines from that source to the local Ottawa broadcast stations since 1923.

The first regularly broadcast transmissions from the Observatory were experimental, supplied by low-power battery-operated transmitters on wavelengths of 20.41, 40.82, and 90 meters because of their proximity to the bands used by Radio Amateurs, who at that time were the main users of "short" waves. In 1929 the

This is the antenna for 7335 kHz. The guys are fiberglass, believed to be the first such use in Canada (*photo courtesy Canadian National Research Council*).

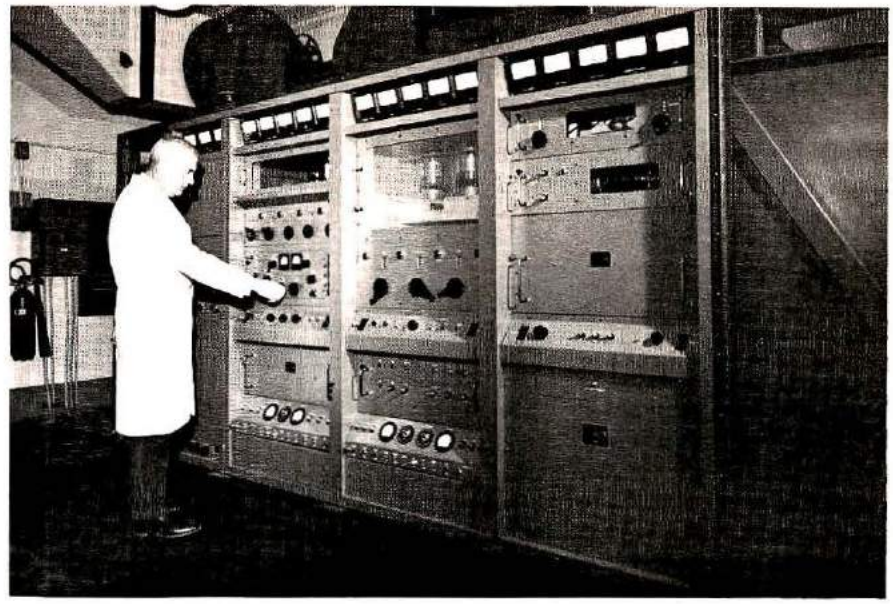


callsign VE9OB was authorized, and reasonably consistent, full-time transmissions began.

In 1942 the time service station was operating under the call CHU, using three 75-watt transmitters, with the call identified in Morse code. In 1946, power was increased to 500 watts, and in 1954, recorded voice announcements replaced the code. These, as well as the time signal pulses, originated in the Observatory and were sent to the transmitter site — approximately ten miles away — over telephone lines.

During 1960, a completely self-contained system was developed and installed at the transmitter site. The system consisted of relatively stable crystal oscillators which provided the basic source for synthesizing the three operating frequencies: 3330, 7335, and 14670 kHz. The crystal oscillators also provided the source for operating the synchronous motor-driven clocks which controlled the time signal. At the same time an automatic recording for the voice announcement was installed.

In 1963 the crystal units were replaced by an atomic frequency standard, and the electro-mechanical clocks by solid-state digital units. In 1964 English-French language voice



The 40-kW, 7335-kHz, transmitter at CHU. VE3BCL at the controls (*photo courtesy Dominion Observatory*).

drums were installed, and the present identification established. On April 1, 1970, the Canadian National Research Council assumed responsibility for Canadian time services, including the operation of CHU.

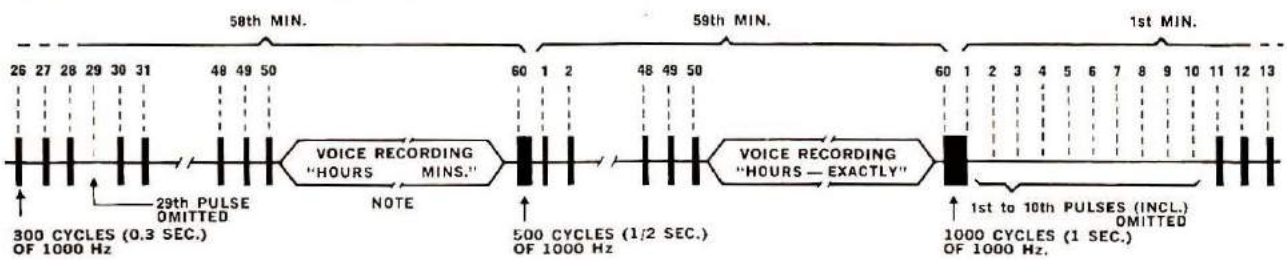
Who uses CHU?

The first users of CHU's services were scientific and survey parties. In fact, the initial "wireless" transmissions from the Observatory were made to a nearby field seismological station to coordinate field results with those obtained at the Observatory. Since those early days, gradual but steady improvements in consistency of service, accuracy of information, and output power have increased the usefulness and range of CHU to a point where anyone possessing even the most inexpensive short wave receiving set can use the Time Service.

Data transmitted by CHU

The broadcasting format of CHU is shown in **Fig. 6**. Three types of information are provided: Standard frequency,

Fig. 6. CHU Data transmission sequence (*information courtesy Canadian National Research Council*).


58th MIN.
59th MIN.
1st MIN.
26 27 28 29 30 31
48 49 50
60 1 2
48 49 50
60 1 2 3 4 5 6 7 8 9 10 11 12 13
VOICE RECORDING "HOURS MINS."
VOICE RECORDING "HOURS — EXACTLY"
29th PULSE OMITTED
NOTE
1st to 10th PULSES (INCL.) OMITTED
300 CYCLES (0.3 SEC.) OF 1000 Hz
500 CYCLES (1/2 SEC.) OF 1000 Hz
1000 CYCLES (1 SEC.) OF 1000 Hz.

NOTE: VOICE RECORDINGS ALTERNATE IN FRENCH AND ENGLISH:

"CHU CANADA, EASTERN STANDARD TIME	HOURS	MINUTES	HEURES	MINUTES"	(EVEN MINUTES)
"CHU CANADA, HEURE NORMALE DE L'EST	HEURES	MINUTES	HOURS	MINUTES"	(ODD MINUTES)
"CHU CANADA, EASTERN STANDARD TIME	HOURS EXACTLY"		HEURES PRÉCISES"		(ON THE HOUR)

CHU IS LOCATED ON THE SOUTH WEST OUTSKIRTS OF OTTAWA AT 45° 17' 47" N, 75° 45' 22" W.

Transmitters line both sides of the corridor. The small units on the right are standby transmitters, which have been replaced by higher-powered ones. An automatic monitoring and switching system is used to change to a standby transmitter in case of failure, and to sound an alarm to bring an operator to fix the trouble (*photo courtesy Canadian National Research Council*).

standard time, and a means of automatically updating compatible digital clocks.

Frequency. CHU's basic frequency source is a cesium atomic standard which is used to control the three broadcast frequencies to an accuracy better than a few parts of a cycle. It must be remembered, however, that broadcasts for precision calibration purposes are affected by signal propagation delays which vary depending upon the distance from the transmitter site, and by delays which occur in the display and receiving equipment itself. For example, when the National Research Council compares signals from WWV, Fort Collins, Colorado, with CHU's transmissions, a delay of seven milliseconds must be included in the calibration calculations!

Time. Eastern Standard Time is transmitted by CHU in the form of tone pulses identified by voice announcements in English and French. The time is based on the atomic second which *gains* on Universal Time at the rate of about one second per year. This is adjusted by one second, exactly, when required — usually on either December 31st or June 30th of each year.*

*Years ago, the measurement of time was based on rotation of the earth (Universal Time, UT) which was shown to lack uniformity. Astronomers then adopted the period of revolution of the earth around the sun for the year 1900 as the basis for the measurement of time, and called it *Ephemeris Time*. Ephemeris Time forms the basis for all astronomical calculations and forecasts, but is not readily available for day-to-day use.

As physical sciences developed, the pendulum yielded to the quartz clock and then to the atomic clock as the primary time keeper. Today, the cesium atomic clock is the primary source of accurate time measurement, because in 1967 the International Bureau of Weights and Measures defined the second as 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium 133 atom. This offered a firm and unchanging basis for scientists of the world to standardize their previously varied measurements.

CHU today

CHU is celebrating its "Golden Anniversary" this year, and invites interested persons to visit the facilities, 15 miles (24 km) from the center of Ottawa, where station personnel will conduct them on guided tours of the installation.

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The Division of Physics of the National Research Council of Canada has published a comprehensive, illustrated, booklet in French and English titled *Standards of Time and Frequency in Canada*, which throughly discusses the cesium atomic clocks, how they are set up and maintained, and touches on future standards, plans, and techniques. **HRH**